

Design of Pyrolyzer Multistage Condensation System to Improve the Quality Natural Preservatives of Fisheries Products

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Abstract— Fish is a rapidly decomposing source of animal protein, so good handling is important to ensure that the quality of the fish is preserved. How the freshness of fish meat can be preserved can be accomplished through the preservation process. By adding natural ingredients that can prevent the growth of bacteria using liquid smoke, one way of preserving fish meat can be achieved. However, in a traditional way, the application of producing liquid smoke is also carried out such that the resulting liquid smoke still contains ash, tar and carcinogenic compounds. In this research, a pyrolyzer made from stainless steel 304 was designed, with a pyrolysis reactor with a capacity of 10 kg coconut shell and a multi-stage condensation system whose working principle utilizes the properties of smoke molecules that tend to flow or move from the bottom up, so that the higher the quality of the smoke molecules the better because they do not contain Ashes from combustion which cause the creation of carcinogenic Polycyclic Aromatic Hydrocarbon (PAH) compounds. The research method includes planning the pyrolyzer design, selecting engineering materials, procedures for making liquid smoke made from coconut shells, pyrolyzer performance test, testing the chemical content of liquid smoke.

I. INTRODUCTION

Fish is a source of animal protein which is rapidly decomposing, therefore it is necessary to have good handling so that the quality of the fish is maintained. How to maintain the freshness of fish meat can be reached through the preservation process. One way of preserving fish meat can be done by adding natural ingredients that can inhibit the development of bacteria by using liquid smoke.

Liquid smoke is a liquid condensate resulting from the decomposition of compounds in raw materials using heat which is then condensed, which is called pyrolysis (Destiyantono et al. 2017). Liquid smoke contains the main constituent compounds of acids, phenols, and carbonyls, so that it can be applied as a

natural preservative in food and provides sensory forms of aroma, color, and distinctive taste in food products, as an anti-bacterial which can inhibit the activity of *S. aureus*, *P. aeruginosa*, *E. coli* and *C. albicans* (Fathussalam et al. 2019).

The use of liquid smoke must comply with SNI 2725.(1).2009, concerning requirements for quality and safety of smoked products as well as preservative content allowed for food and beverage products that are traded. According to (Rasi and Seda 2014) the main requirements for liquid smoke products can be used as a preservative for food products, among others;

- Should not contain Polycyclic Aromatic Hydrocarbon (PAH) more than 0.05 µg / kg of liquid smoke, PAH compounds can be carcinogenic, among the PAH

compounds that are often used as an indicator of PAH safety level is benzo (a) pyrene because it has the highest carcinogenic properties.

- b) If the pH value is low, it means that the smoke produced is of high quality, especially in terms of its use as a food preservative. The low pH value as a whole has an effect on the longevity and shelf life of the smoke product or its organoleptic properties. The standardized pH value set is 1.50-3.70.
- c) Apart from being free from hazardous compounds, liquid smoke used as a food preservative must have a flavor that is acceptable to consumers.

However, because the pyrolysis used to produce liquid smoke is still in the form of a cylinder made of iron plate which comes from used lubricating oil drums which generally rust easily causes the resulting liquid smoke to contain iron (Fe), ash, tar and other carcinogenic compounds that do not meet the requirements. Liquid smoke quality standard according to SNI 01-2891-1992.

In this research, a pyrolyzer was designed with 304 stainless steel material, which is equipped with a pyrolysis reactor with a capacity of 10 kg coconut shell and a condensation system whose working principle utilizes the properties of smoke molecules that tend to flow or move from the bottom up, so that the higher the quality of the smoke molecules the better because does not contain ash from combustion and prevents the creation of Polycyclic Aromatic Hydrocarbon (PAH) compounds. Thus, the pyrolyzer design with a multilevel condensation system can produce liquid smoke with food grade quality which is safe for use as a natural preservative and as a food aroma enhancer.

II. RESEARCH METHODS

This research is divided into several stages, including the design of the pyrolyzator design, testing the performance of the pyrolyzer on the volume and testing the chemical content of liquid smoke. The pyrolysis design planning in this study was carried out using a comparative method, namely by comparing the theory (literature study) with the results of field observations (field observation). Meanwhile, in the pyrolyzer design activity in this study using the Trail and Learn method, which is to design and test the pyrolysis performance, then evaluate and improve the product until it is in accordance with the objectives to be achieved.

Tools and Materials

The equipment used to design and test the pyrolyzers in this study consisted of; Welding machines, grinding machines, roll machines, drilling machines, meters, elbow rulers, calipers, vise, pH indicator paper, thermometers, measuring cups, stoves and scales.

The materials used to design and test the pyrolyzers in this study include; stainless plate 2 mm, stainless steel pipe 1.5 inch, stainless steel electrode, galvanized iron 4x4 cm, putty, door hinge, nuts and bolts, LPG, coconut shell and sampling bottle.

Design

The design is a set of procedures to translate the results of the analysis of a theory to design to describe in detail how the components are implemented, while the construction is the activity of creating new designs and replace or repair the existing design as a whole (R. Pressman., 2002 dalam Buchari et al., 2015).

In conducting designing activities there are some important factors that must be considered diantaranya; strength, stiffness, resistance, corrosion resistance, price, formability (Asikin 2011).

Functional Pyrolysis Design

Functional design describes the functions that can be performed by the components of the pyrolyzer (Hasanah 2013). The pyrolysis in this study has three main components that have different functions from one another. To explain the function of the components contained in the multi-store pyrolysis condensing system, described as follows:

- a. The pyrolysis reactor functions as a place for the pyrolysis process or the breakdown of chemical compounds from the coconut shell through the heating process, thus causing the decomposition process, namely the breakdown of chemical bonds in thermal terms and the decomposition of coconut shell organic compounds consisting of gas, tar and charcoal.
- b. The condenser functions to change the form of the combustion gas into a liquid form called liquid smoke. The process of changing from gas to liquid form occurs because of condensation or heat transfer in a spiral-shaped pipe which is cooled by cooling water.
- c. The connecting pipe functions to flow gas or smoke from the combustion of coconut shells in the pyrolysis reactor to a room that has a lower temperature (condenser).

Pyrolyzer Structural Design

Structural design is the analysis of the components of the tools that will be created that has been discussed in the functional design, (Hasanah 2013). Structural design done to determine the shape, size, and

material of each component. Design pyrolyzer with multistage condensation system in this study, can be seen in Figure 1.

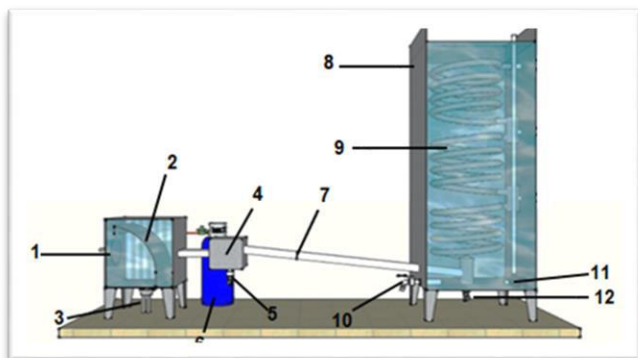


Fig.1: Design pyrolyzermultistage condensation system

Keterangan;

- | | |
|----------------------|-------------------------------------|
| 1. pyrolysis reactor | 7. connecting pipe |
| 2. soot separator | 8. condenser tube |
| 3. gas burner | 9. condenser pipe |
| 4. tar container | 10. Cooling water discharge channel |
| 5. tar exhaust | 11. liquid smoke distillate channel |
| 6. Gas | 12. Tar drainage |

Pyrolyzer Performance Testing and Liquid Smoke Quality

The pyrolyzer test conducted in this study aims to determine the performance of the pyrolyzator with a multilevel condensation system. The tests carried out include; Observations heating temperature, heating rate analysis, yield analysis Liquid Smoke. Meanwhile, testing the quality of liquid smoke is an important parameter to determine the chemical content and product safety for consumers, in considering the selection of natural preservatives are used. The tests performed, among others; Analysis of pH value, Abu Content Analysis, Analysis of Water Content of Liquid Smoke and toxicity.

The results of testing the pyrolysis performance and the quality of liquid smoke produced by pyrolyzers with a multilevel condensation system in this study were also compared with conventional methods used in the CV Wulung Prima liquid smoke industry and previous research.

III. RESULT AND DISCUSSION

Design pirolisator in this study, is the result of the collection of data and information about the advantages and disadvantages pirolisator used in

industrial liquid smoke and previous research. The collection of data and information is done through literature studies and field observations, which are then compared on a causal and contributing factors, in order to create the fundamental answer applied into a pirolisator design in accordance with the planned concept. The results of the pyrolysis design with a multilevel condensation system can be seen in Figure 2.



Fig.2: Pyrolyzers with multilevel condensation system

The working principle of a pyrolyzer with a multilevel condensation system is to take advantage of the properties of smoke molecules that tend to flow or move from the bottom up, so that the higher the quality of the smoke molecules the better because they do not contain ash, tar and carcinogenic compounds resulting from burning coconut shells.

Pyrolysis Reactor

The pyrolysis reactor is a place for the pyrolysis process or the breakdown of chemical compounds from coconut shells through a heating process with a temperature of 100-500°C. A method of heating the raw material coconut shell in this study, using the system indirectly. The indirect combustion method aims so that the flame does not directly hit the coconut shell raw material but only at the pyrolysis reactor, so it is believed to prevent the creation of Polycyclic Aromatic Hydrocarbon (PAH) compounds.

The parameter used as a reference for calculating the dimensions of this pyrolysis reactor is the capacity of the raw material (coconut shell) used. It is known that the density of coconut shells from the results of preliminary research is 68.5 kg / m³, (Hasanah 2013). Specifications pyrolysis reactor to process 10 kg of coconut shell can be seen in Table 1.

Table 1. Specifications pyrolysis reactor

Section	Dimensions	Size
Pyrolysis Reactor	Height	50 Cm

Reactor Door	Length	50 Cm
	Width	40 Cm
	Height	30 Cm
	Width	30 Cm
Stanchion	Height	20 cm

Condenser

The condenser is a tool that functions to change the form of the combustion gas into a liquid form, because of the condensation process or heat transfer in a spiral-shaped pipe cooled by cooling water. The condensation process causes the binding of water vapor molecules to become water particles, so that the smoke from the combustion does not come out and pollute the surrounding air and increase the amount of liquid smoke produced from the melting of the smoke from the combustion of coconut shells.

The condenser designed in this study can accommodate 432 liters of cooling water. Specifications condenser in this study are shown in Table 2.

Table 2. Specifications Condenser

Section	Dimensions	Size
Condenser Tube	Height	120 Cm
	Length	60 Cm
	Width	60 Cm
Condenser Pipe	Diameter	1Inchi
	length	1200 cm

Connecting Pipe

The connecting pipe functions to flow gas or smoke from the combustion of coconut shells in the pyrolysis reactor to a room that has a lower temperature (condenser). The connecting pipe is equipped with a tar container which functions to prevent tar compounds from being carried by the gas or smoke from the burning of the coconut shell into the condenser.

The connecting pipe is equipped with a union socket which functions as a connection for the two pipes so that the pipe installation can be assembled, so that it can facilitate the maintenance and repair process in case of damage to one of the main components of the pyrolyzer device. The connecting pipe specifications for the multi-level condensing pyrolysis system can be seen in Table 3.

Table 3. Connecting Pipe Specifications

Section	Dimensions	Size
Connecting Pipe	Length	120 Cm

Penampung Tar	Diameter	1 inch
	Length	20 cm
	Height	20 cm
	Width	20 cm

Pyrolyzer Performance Testing.

The pyrolyzer performance test in this study was carried out in three treatments, what distinguished each treatment was the volume of coconut shell that would be used as raw material for making liquid smoke. The first treatment (A) was 2.5 kg, the second treatment (B) was 5 kg and the third treatment (C) was 10 kg coconut shell and each treatment was carried out three times. The pyrolyzer performance test was carried out with several test parameters, including the ratio of time to temperature and yield of liquid smoke.

Pyrolysis Temperature Observation

Temperature observations conducted in order to determine the rate of warming in the pyrolysis reactor. Observation of temperature is carried out every 30 minutes, during the pyrolysis process by observing the thermometer in the pyrolysis reactor and recording the amount of heating temperature into the observation table. The results of temperature observations during the study can be seen in Figures 3, 4 and 5.

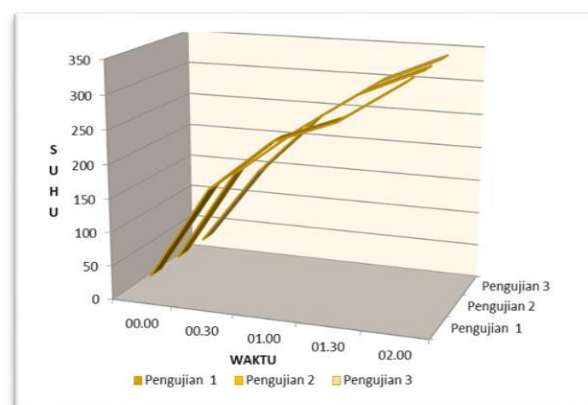


Fig.3: The observation of the pyrolysis temperature with 2.5 kg of coconut shell

Annotation;

- The time required for the pyrolysis process is 2 hours.
- The temperature needed to produce liquid smoke starts at a temperature of 110°C
- Temperature 110°C reached within 12 minutes.
- The heating rate of the pyrolyzer is 1.25 kg / hour

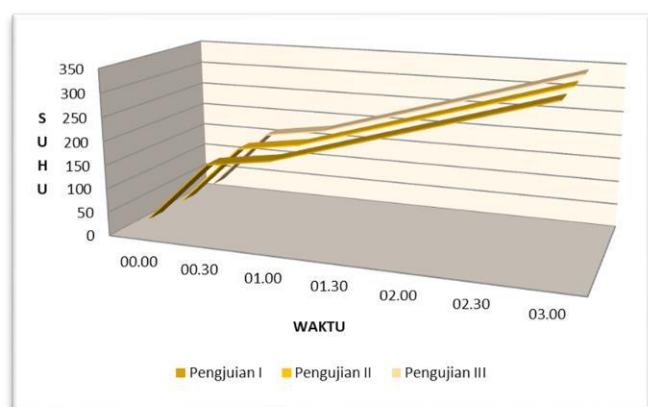


Fig.4: The observation of the pyrolysis temperature with 5 kg of coconut shell

Annotation;

- The time required for the pyrolysis process is 3 hours.
- The temperature needed to produce liquid smoke starts at a temperature of 110°C
- Temperature 110°C reached within 12 minutes.
- The heating rate of the pyrolyzer is 1.7 kg / hour

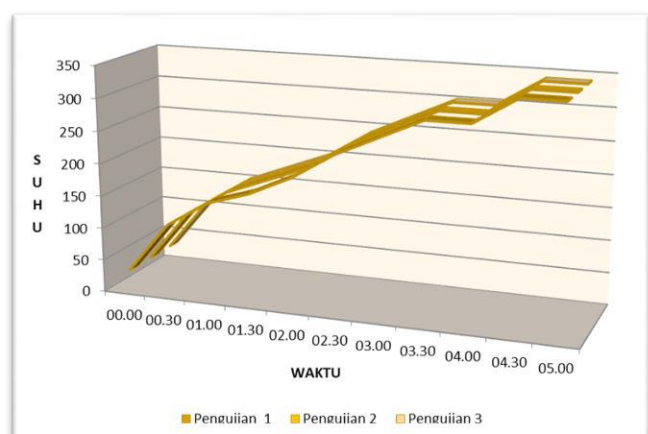


Fig.5: The observation of the pyrolysis temperature with 10 kg of coconut shell

Annotation;

- The time required for the pyrolysis process is 5 hours.
- The temperature needed to produce liquid smoke starts at a temperature of 110°C
- Temperature 110°C reached within 20 minutes.
- The heating rate of the pyrolyzer is 2 kg / hour

From observations made on pyrolyzer with multilevel condensing system, the weight of coconut shell used for the process of making liquid smoke affect the time required. The greater the weight of coconut shell raw materials led to the burning time is increasing.

The temperature needed to produce liquid smoke starts at a temperature of 110°C, in treatment I and II it takes 12 minutes to reach a temperature of 110°C, while in treatment III it takes 20 minutes. To produce the maximum liquid smoke is done at a temperature of 200-300°C, because at that temperature the amount of liquid smoke is greater than temperatures below 200°C. the maximum temperature reached by pyrolysis are 340°C, at this temperature the coconut shell is used as a raw material for making liquid smoke had turned into charcoal. When the coconut shell becomes charcoal, the pyrolysis process is stopped, because it affects the yield of liquid smoke.

Yield of Liquid Smoke

The variable measured to obtain the yield of liquid smoke is the ratio of the volume of liquid smoke produced to the mass of the coconut shell raw material used. Measurement of the volume of liquid smoke produced was carried out using a measuring cup with a scale of 100 ml, while to measure the weight of the coconut shell using a digital scale. The yield of liquid smoke can be seen in table 4.

Table 4. Yield of Liquid Smoke

Treatment	Repeat	volume of liquid smoke (liter)	Yield (%)
A	I	0,6	24
	II	0,5	20
	III	0,6	24
	Average	0,57	22,7
B	I	1,2	24
	II	1,1	22
	III	1,1	22
	Average	1,13	22,7
C	I	2,4	24
	II	2,3	23
	III	2,4	24
	Average	2,37	23,7

From the results of tests performed, explaining that the value rendement liquid smoke obtained from pyrolysis with terraced condensation system is between 20-24%. The reactor temperature pyrolysis to produce liquid smoke on pyrolysis maximum is between 200-300°C, so the longer the process of pyrolysis at temperatures 200-300°C cause decomposition of chemical compounds in coconut shell more perfect, so that the resulting liquid smoke more.

The yield of liquid smoke produced by a pyrolyzer with a multilevel condensation system is 20-24%. The conventional pyrolyzer used by CV. Wulung Prima has a liquid smoke yield of 7%. Meanwhile, the pyrolyzer based on cyclone-redistillation technology (Fathussalam et al. 2019) had a liquid smoke yield of 13.3% and a stratified shell liquid smoke distillation pyrolyzer (Suherman and Alfansuri 2019) had a liquid smoke yield of 12%.

Chemical Content Testing of Liquid Smoke

This research produces liquid smoke with food grade quality, reddish brown in color, and has a strong odor. Meanwhile, the chemical content of liquid smoke produced from pyrolyzers with a multilevel condensation system is described as follows;

Liquid Smoke pH Analysis

Measuring the pH value of liquid smoke from coconut shells aims to determine the degree of acidity of the process of decomposing raw materials by pyrolysis. Measurement of pH values was carried out using pH litmus paper with the brand MQuant, which has a measurement range of 0-14 pH scale with a series of 4 (four) colors on each strip. Measurement is done by means of; prepare the liquid smoke sample to be tested, then soak the litmus paper into the liquid smoke sample. After 30 seconds remove the litmus paper and see the color change on the litmus paper. Finally, match and compare it with the acidity table that is listed in the box.

The pH value of liquid smoke as a result of this study is 2, which means that the pH value of the liquid smoke produced by the pyrolyzer with a multilevel condensation system is smaller than the liquid smoke produced by CV Wulung Prima with a pH value of 3. The results of this study meet the quality standard value of liquid smoke because it meets the pH value range of 1.50-3.70. Low pH value means that the liquid smoke produced is of high quality, especially in terms of its use as a food preservative. Overall low pH value affects the longevity and shelf life of a product.

Ash Content

Ash content testing was carried out using the AOAC 2012 method. The method of testing begins with weighing the sample of 2 grams of liquid smoke, put it in a porcelain cup and place it in a furnace at 600 suhuC for 2 hours. Subsequently, the cup was cooled for 30 minutes in the desiccator then weighed heavy porcelain dish and ash percentages written to 1 decimal behind the comma. The calculation of the ash content uses the following formula;

$$\text{Ash Content} = \frac{W1-W2}{W} \times 100\%$$

Description;

W : footage weight (g)

W1 : Sample weight + Cup after ignition (g)

W2 : Weight empty cup (g)

Ash content testing aims to determine the value of a material left in the liquid smoke. Ash is an inorganic residue from the combustion or oxidation process of coconut shell organic components. The ash content resulted from testing the liquid smoke in this study was 0.21%. The results of the ash content test can be seen in table 5

Table 5. Ash Content Lab Test Results

Parameter	Result	Unit	Method
Ash Content	0,21	% w/w	AOAC (2012) 942.05

Water Content And Toxicity Test in Liquid

Water content and toxicity tests were carried out to identify components of coconut shell liquid smoke using the Gas Chromatography-Mass Spectroscopy (GC-MS) method. In conducting the test, it was carried out using 30 ml of liquid smoke into a separating flask, then added with 10 ml of dichloromethane and shaken for a while. The sample was allowed to stand for 1 hour and then taken the lower fraction and added to the first, and filtered with Whatman 42 paper with added Na₂SO₄.

Testing the toxicity of liquid smoke using Gas Chromatography-Mass Spectroscopy (GC-MS) aims to ensure the food safety of coconut shell liquid smoke produced by pyrolyzers with a multilevel condensation system. Results of laboratory tests conducted on laboratory services unit testing, calibration and certification of Bogor Agricultural Institute (IPB), indicating that the compound benzo [a] pyrene is not found in liquid smoke, for more details the results of the water content and toxicity test in liquid smoke can be seen in table 6.

The compounds identified from the liquid smoke made from coconut shells in this study include:

a. Phenolic compounds.

The biggest component identified was phenol with a value of 56.14%, meaning that phenol compounds constitute the majority of the liquid smoke components produced from coconut shell raw materials. Phenol has a role as anti-oxidant and flavor giver in food, especially smoked fish. Phenolic compounds contained in liquid smoke include 2,6-Dimethoxyphenol 6,89%, 2-Methoxyphenol 6,77%, 2-methylphenol 3,14%, 3-Methylphenol 2,84%, 4-Ethyl-2-methoxyphenol 1,17%, 2-Methoxy-4-methylphenol 1,73%.

b. Carbonyl compounds.

Carbonyl compounds in liquid smoke have a role in the coloring and flavor of the smoke product. This class of compounds has a unique caramel-like aroma. The types of carbonyl compounds contained in liquid smoke include vanillin, siringaldehyda.

c. Acidic compounds.

Acidic compounds have an antibacterial role and form the flavor of the smoke product. Acid compounds include acetic acid, propionate butyrate and syringaldehyde

In general, coconut shell liquid smoke produced from pyrolyzers with a multilevel condensation system can be used as a natural preservative and aroma enhancer for food products that are safe for consumption, because harmful compounds are not found.

Table 6. The water content and toxicity test in liquid smoke

Parameter	Result	Unit	Technique
Phenol	56.14	%Area	GC-MS
3,4-Dimethyl-3-pentene-2-one	0.23	%Area	GC-MS
1-Hydroxy-2-pentanone	0.29	%Area	GC-MS
3-Methylcyclopentane-1,2-dione	2.25	%Area	GC-MS
2,3-Dimethylcyclopent-2-en-1-one	0.27	%Area	GC-MS
2-Methylphenol	3.14	%Area	GC-MS
2,4-Dimethyl-1,3-cyclopentanedione	0.22	%Area	GC-MS
Butanoic acid, phenyl ester	0.38	%Area	GC-MS
3-Methylphenol	2.84	%Area	GC-MS
2-Methoxyphenol	6.77	%Area	GC-MS
4-Pentylcyclohexanone	0.30	%Area	GC-MS
3-Hydroxy-2-methyl-1,4-pyrone	0.25	%Area	GC-MS
3-Ethyl-2-hydroxy-2-cyclopenten-1-one	0.57	%Area	GC-MS
2-Ethylphenol	0.31	%Area	GC-MS
Phenol, 2,4-dimethyl-, acetate	0.81	%Area	GC-MS
Benzoic acid	0.09	%Area	GC-MS
1,2-Benzenediol	2.95	%Area	GC-MS
2-Methoxy-4-methylphenol	1.73	%Area	GC-MS
2-Isopropoxyphenol	0.21	%Area	GC-MS
3-Methyl-1,2-benzenediol	0.85	%Area	GC-MS
3-Methoxy-1,2-benzenediol	1.66	%Area	GC-MS
4-Ethyl-2-methoxyphenol	1.17	%Area	GC-MS
4-Methyl-1,2-benzenediol	1.36	%Area	GC-MS
2,6-Dimethoxyphenol	6.89	%Area	GC-MS
4-Ethyl-1,2-benzenediol	0.83	%Area	GC-MS
Vanillin	0.30	%Area	GC-MS
2-Methoxy-5-[(1E)-1-propenyl]phenol	0.05	%Area	GC-MS
Allyl 3-methoxybenzoate	0.36	%Area	GC-MS
3,5-Dimethoxy-4-hydroxytoluene	1.47	%Area	GC-MS
Methylparaben	0.90	%Area	GC-MS
1-(3-Hydroxy-4-methoxyphenyl)ethanone	0.34	%Area	GC-MS
4-Hydroxybenzoic acid	0.41	%Area	GC-MS
Gallacetophenone-4'-methylether	0.78	%Area	GC-MS
1-(4-Hydroxy-3-methoxy-phenyl)-propan-2-one	0.95	%Area	GC-MS
4-Hydroxy-3,5-dimethoxybenzaldehyde	0.26	%Area	GC-MS
1-(4-Hydroxy-3,5-dimethoxyphenyl)ethanone	0.21	%Area	GC-MS
Coniferyl aldehyde	0.33	%Area	GC-MS
1-(4-Hydroxy-3,5-dimethoxyphenyl)-2-propanone	1.00	%Area	GC-MS
3,3,8a-Trimethyl-6-oxodecahydro-1-naphthalenyl	0.13	%Area	GC-MS

IV. CONCLUSION

Based on the research results, the pyrolysis design with a multilevel condensation system, it can be concluded that; Pyrolyzers with multilevel condensation systems whose working principle take advantage of the properties of smoke molecules that tend to flow or move from the bottom up, so that the higher the quality of the smoke molecules the better because they do not contain ash, soot and tar from combustion, very suitable for use in the liquid smoke industry, because it can produce liquid smoke yield of 23.7% or 2.3 liters in 5 hours from 10 kg of coconut shell raw material. Liquid smoke generated from research can be used as a food preservative. This is because the pH value of liquid smoke is 2, the ash content is 0.21% and does not contain benzo [a] pyren compounds which are carcinogenic through GC-MS testing. which means it meets the value of the liquid smoke quality standard according to SNI 01-2891-1992.

Based on the results and discussion of research activities engineering and design pirolisator with terraced condensation system, it is suggested for further research to take into account the effect of the condensation pipe diameter to the volume of liquid smoke and the influence of the type of raw materials to product quality liquid smoke produced.

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